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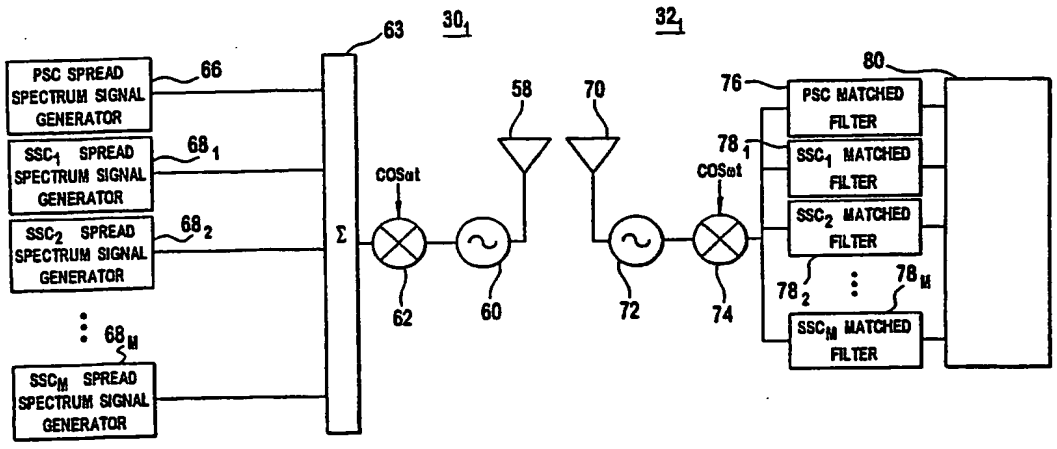
(54) **Title:** CELL SEARCH PROCEDURE FOR TIME DIVISION DUPLEX COMMUNICATION SYSTEMS USING CODE DIVISION MULTIPLE ACCESS



(57) **Abstract:** A base station sends a synchronization signal in an assigned time slot to a user equipment in a time division duplex code division multiple access communication system. The base station has an assigned code group out of a predetermined number of code groups. The base station transmits selected secondary synchronization code signals out of a set of secondary synchronization code signals. The plurality of secondary synchronization code signals numbers less than half of the predetermined number of code groups. The user equipment identifies the transmitted selected secondary code signals. Based on in part the identified secondary synchronization code signals, the assigned code group is determined.

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CELL SEARCH PROCEDURE FOR TIME DIVISION DUPLEX COMMUNICATION SYSTEMS USING CODE DIVISION MULTIPLE ACCESS

BACKGROUND

This invention generally relates to spread spectrum Time Division Duplex (TDD) communication systems using Code Division Multiple Access (CDMA). More particularly, the present invention relates to cell search procedure of User Equipment (UE) within TDD/CDMA communication systems.

Figure 1 depicts a wireless spread spectrum TDD/CDMA communication system. The system has a plurality of base stations $\mathbf{30_1}$ to $\mathbf{30_7}$. Each base station $\mathbf{30_1}$ has an associated cell $\mathbf{34_1}$ to $\mathbf{34_7}$ and communicates with user equipments (UEs) $\mathbf{32_1}$ to $\mathbf{32_3}$ in its cell $\mathbf{34_1}$.

In addition to communicating over different frequency spectrums, TDD/CDMA systems carry multiple communications over the same spectrum. The multiple signals are distinguished by their respective code sequences (codes). Also, to more efficiently use the spectrum, TDD/CDMA systems as illustrated in **Figure 2** use repeating frames **38** divided into a number of time slots $\mathbf{36_1}$ to $\mathbf{36_{n,}}$, such as sixteen time slots 0 to 15. In such systems, a communication is sent in selected time slots $\mathbf{36_1}$ to $\mathbf{36_n}$ using selected codes. Accordingly, one frame **38** is capable of carrying multiple communications distinguished by both time slot $\mathbf{36_1}$ to $\mathbf{36_n}$ and code.

For a UE 32_1 to communicate with a base station 30_1, time and code synchronization is required. **Figure 3** is a flow chart of the cell search and synchronization process. Initially, the UE 32_1 must determine which base station 30_1 to 30_7 and cell 34_1 to 34_7 to communicate. In a TDD/CDMA system, all the base stations 30_1 to 30_7 are time synchronized within a base station cluster. For synchronization with UEs 32_1 to 32_7, each base station 30_1 to 30_7 sends a Primary Synchronization Code (PSC) and several Secondary Synchronization Code (SSC) signals in the time slot dedicated for synchronization. The PSC signal has an associated chip code, such as an unmodulated 256 hierarchical code, and is transmitted in the dedicated time slot, step **46**. To illustrate, a base station 30_1 may transmit in one or two time slots, such as for a system using time slots 0 to 15 in time slot K or slot K+8, where K is either 0, ..., 7.

One technique used to generate a PSC signal is to use two 16 hierarchical sequences, such as X1 and X2 in **Equations 1** and **2**.

$$X1 = [1, 1, -1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, 1, -1] \quad \textbf{Equation 1}$$

$$X2 = [1, 1, -1, -1, -1, -1, 1, -1, 1, 1, -1, 1, 1, 1, -1, 1] \quad \textbf{Equation 2}$$

Equation 3 illustrates one approach to generate a 256 hierarchal code, y(i), using X1 and X2.

$$y(i) = X1\ (i \bmod 16) \times X2\ (i \operatorname{div} 16), \text{ where } i = 0, ..., 255 \quad \textbf{Equation 3}$$

Using y(i), the PSC is generated such as by combining y(i) with the first row of length 256 Hadamarad matrix, h_0, to produce $C_p(i)$ as in **Equation 4**.

$$C_p(i) = y(i) \times h_0(i), \text{ where } i = 0, ..., 255 \qquad \textbf{Equation 4}$$

Since the first row of the Hadamarad matrix is an all one sequence, **Equation 4** reduces to **Equation 5**.

$$C_p(i) = y(i), \text{ where } i = 0, ..., 255 \qquad \textbf{Equation 5}$$

The $C_p(i)$ is used to produce a spread spectrum PSC signal suitable for transmission.

To prevent the base stations' communications from interfering with each other, each base station $\mathbf{30_1}$ to $\mathbf{30_7}$ sends its PSC signal with a unique time offset, t_{offset}, from the time slot boundary **40**. Differing time offsets are shown for time slot **42** in **Figure 4**. To illustrate, a first base station $\mathbf{30_1}$ has a first time offset $\mathbf{44_1}$, $t_{offset,1}$ for the PSC signal, and a second base station $\mathbf{30_2}$, has a second time offset $\mathbf{44_2}$, $t_{offset,2}$.

To differentiate the different base stations $\mathbf{30_1}$ to $\mathbf{30_7}$ and cells $\mathbf{34_1}$ to $\mathbf{34_7}$, each base station $\mathbf{30_1}$ to $\mathbf{30_7}$ within the cluster is assigned a different group of codes (code group). One approach for assigning a t_{offset} for a base station using an n^{th} code group $\mathbf{44_n}$, $t_{offset,n}$ is **Equation 6**.

$$t_{offset,n} = n \cdot 71T_c \qquad \textbf{Equation 6}$$

T_c is the chip duration and each slot has a duration of 2560 chips. As a result, the offset 42_n for each sequential code group is spaced 71 chips.

Since initially the UE 32_1 and the base stations 30_1 to 30_7 are not time synchronized, the UE 32_1 searches through every chip in the frame **38** for PSC signals. To accomplish this search, received signals are inputted to a matched filter which is matched to the PSC signal's chip code. The PSC matched filter is used to search through all the chips of a frame to identify the PSC signal of the base station 30_1 having the strongest signal. This process is referred to as step-1 of cell search procedure.

After the UE 32_1 identifies the PSC signal of the strongest base station 30_1, the UE 32_1 needs to determine the time slot 36_1 to 36_n in which that PSC and SSC signals are transmitted (referred to as the Physical Synchronization Channel (PSCH) time slot) and the code group used by the identified base station 30_1. This process is referred to as step-2 of cell search procedure. To indicate the code group assigned to the base station 30_1 and the PSCH time slot index, the base station 30_1 transmits signals having selected secondary synchronization codes (SSCs), step **48**. The UE 32_1 receives these SSC signals, step **50**, and identifies the base station's code group and PSCH time slot index based on which SSCs were received, step **52**.

For a TDD system using 32 code groups and two possible PSCH time slots per frame, such as time slots K and K+8, one approach to identify the code group and PSCH time slot index is to send a signal having one of 64 SSCs. Each of the synchronization codes corresponds to one of the 32 code groups and two possible

PSCH time slots. This approach adds complexity at the UE 32_1 requiring at least 64 matched filters and extensive processing. To identify the code group and PSCH time slot index, 17,344 real additions and 128 real multiplications are required in each PSCH time slot and 64 real additions are required for the decision.

An alternative approach for step-2 of cell search procedure uses 17 SSCs. These 17 SSCs are used to index the 32 code groups and two possible PSCH time slots per frame. To implement this approach, at least 17 matched filters are required. To identify the code group and time slot, 1,361 real additions and 34 real multiplications are required for each PSCH time slot. Additionally, 512 real additions are required for the decision.

It would be desirable to reduce the complexity required by a UE 32_1 to perform cell search procedure.

SUMMARY

A base station sends a synchronization signal in an assigned time slot to a user equipment in a time division duplex code division multiple access communication system. The base station has an assigned code group out of a predetermined number of code groups. The base station transmits selected secondary synchronization code signals out of a set of secondary synchronization code signals. The plurality of secondary synchronization code signals numbers less than half of the predetermined number of code groups. The user equipment identifies the transmitted selected

secondary code signals. Based on in part the identified secondary synchronization code signals, the assigned code group is determined.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a prior art TDD/CDMA system.

Figure 2 illustrates time slots in repeating frames of a TDD/CDMA system.

Figure 3 is a flow chart of cell search.

Figure 4 illustrates time offsets used by differing base stations sending primary synchronization code signals.

Figure 5 is a diagram of the simplified components of a user equipment and a base station using binary phase shift keying modulation for cell search.

Figure 6 is a flow chart of secondary synchronization code assignment.

Figure 7 illustrates the simplified components of a user equipment and a base station using quadrature phase shift keying modulation for cell search.

Figure 8 illustrates the simplified components of a user equipment and a base station reducing the maximum number of transmitted secondary synchronization codes using quadrature phase shift keying modulation.

Figures 9 to **17** are graphs depicting the performance of various synchronization systems under varying simulated channel conditions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments will be described with reference to the drawing figures where like numerals represent like elements throughout. **Figure 5** shows the simplified circuitry of a base station $\mathbf{30_1}$ and a UE $\mathbf{32_1}$ for use in cell search. During step-1 of the cell search, the base station $\mathbf{30_1}$ generates a PSC signal using a PSC spread spectrum signal generator **66** having the time offset in the time slot **42** associated with the base station $\mathbf{30_1}$. The PSC signal is combined by a combiner **63** with M SSC signals. The combined signal is modulated by a modulator **62** to carrier frequency. The modulated signal passes through an isolator **60** and is radiated by an antenna **58** or, alternately, an antenna array.

The UE $\mathbf{32_1}$ receives signals using an antenna **70** or, alternately, an antenna array. The received signals are passed through an isolator **72** where they are demodulated by a demodulator **74** to baseband frequency. During step-1 of the cell search, the PSC matched filter **76** is used by the processor **80** to search through all the chips of a frame **38** to identify the PSC signal of the base station $\mathbf{30_1}$ having the strongest signal.

One approach for detection of a PSC signal location in a frame is as follows. A selected number of positions in the received signal frame, such as forty, having the highest number of accumulated chip matches (i.e. maximum signal strength), are repeatedly correlated at the same positions in subsequent frames **38**. Out of the selected locations, the one having the highest number of cumulative matches (i.e. the maximum signal strength) is identified as the location of the PSC signal.

For step-2 of the cell search procedure, the base station 30_1 generates SSC signals, SSC_1 to SSC_M, using SSC spread spectrum signal generators 68_1 to 68_M. To reduce the complexity at the UE 32_1, a reduced number of SSCs are used. By reducing the SSCs, the number of matched filters required at the UE 32_1 is reduced. Additionally, the reduced SSCs decreases the processing resources required to distinguish the different codes. The reduced SSCs also reduces the probability of incorrect detection of a code group number and PSCH time slot index (see **Figures 9-15**).

One approach to reduce the SSCs is shown in the flow chart of **Figure 6**. The number of SSCs used, M, is based on the number of code groups and PSCH time slots used per frame, step **54**. The number of SSCs, M, is the log base two of the maximum combination number rounded up to the next higher integer, step **56**, as in **Equation 7**.

$$M = \log_2 (\#\text{ of Code Groups} \times \#\text{ of PSCH Time Slots per frame})$$

Equation 7

The base station 30_1 generates, using SSC signal generators 68_1 to 68_M, the SSC signals associated with the base station's code group and the number of PSCH time slots per frame. The SSC signals are combined with each other as well as the PSC signal by combiner **63**. Subsequently, the combined signal is modulated by the modulator **62**, passed through the isolator **60** and radiated by the antenna **58**. The

UE 32_1 receives the transmitted signal, passes it through the isolator **72** and demodulates the received signal using the demodulator **74**. Using corresponding SSC_1 to SSC_M matched filters 78_1 to 78_M, the processor **80** determines the binary code that SSCs are modulated. Based on the determined binary code, the base station's code group and PSCH time slot index in the frame is determined. To illustrate for a system using 32 code groups and two possible time slots per frame, such as slots K and K+8, the number of binary bits needed to modulate SSCs, M, is six ($\log_2 64$). In such a system, the six SSCs are modulated with six bits using binary phase shift keying (BPSK) modulation. The six SSCs are chosen among the 256 rows of Hadamarak matrix, H_8. The Hadamarak matrix is generated sequentially, such as by **Equations 8** and **9**.

$$H_0 = (1) \qquad \textbf{Equation 8}$$

$$H_t = \begin{bmatrix} H_{t-1} & H_{t-1} \\ H_{t-1} & H_{t-1} \end{bmatrix}, \; t = 1,...,8 \qquad \textbf{Equation 9}$$

A particular code, $C_{k,n}(i)$, where n is the code group number associated with a SSC is produced using **Equation 10**. The six rows of Hadamarak matrix, H_8, are r(k) = [24, 40, 56, 104, 120, 136].

$$C_{k,n}(i) = b_{k,n} \times h_{r(k)}(i) \times y(i), \text{ where } i = 0, 1, ..., 255 \text{ and } k = 1, ..., 6$$

Equation 10

The value of b_2 to b_6 are depicted in **Table 1**.

Code Group (n)	$b_{6,n}$	$b_{5,n}$	$b_{4,n}$	$b_{3,n}$	$b_{2,n}$
1	+1	+1	+1	+1	+1
2	+1	+1	+1	+1	-1
3	+1	+1	+1	-1	+1
...	...	...	...	...	...
32	-1	-1	-1	-1	-1

Table 1

The value of $b_{1,n}$ is depicted in **Table 2**.

PSCH time slot order in the frame	$b_{1,n}$
K, where K = 0,...,7	+1
K + 8	-1

Table 2

Each code corresponds to one SSC, SSC_1 to SSC_6. To distinguish the differing base stations' SSC signals from one another, each of the base stations' SSC signals has the same offset as its PSC signal. At the UE 32_1, the step-2 of the cell search procedure (i.e. code group number and PSCH slot order detection) is performed as follows. The received baseband signal is first correlated with C_p as per **Equation 4** to obtain phase reference. This correlation is performed by PSC matched filter **76** in **Figure 5**. The phase reference is obtained by normalizing the correlation value obtained at the output of the PSC matched filter **76**. The received baseband signal is also

correlated with C1,...,C6 as per **Equation 10** to obtain binary data that represent the code group of the base station $\mathbf{30_1}$ and PSCH slot order in the frame. This correlation is performed by SSC matched filters $\mathbf{78_1}$-$\mathbf{78_M}$ in **Figure 5**. These matched filter outputs are derotated before BPSK demodulation. The derotation is performed by complex multiplication of the complex conjugate of the phase reference. The derotated SSC matched filter outputs are BPSK demodulated. The BPSK demodulation is performed by a hard limiter on the real part of the derotated SSC matched filter outputs. As a result, if the real part of the derotated SSC matched filter output is greater than zero, it is demodulated as +1. Otherwise, it is demodulated as -1. The demodulated binary data represents the code group of the base station $\mathbf{30_1}$ and the PSCH time slot order in the frame as depicted in **Table 1** and **Table 2** respectively. To ease detection of the six SSCs, the UE $\mathbf{32_1}$ accumulates the derotated outputs of the SSC matched filters $\mathbf{78_1}$-$\mathbf{78_M}$ over a number of the PSCH time slots, such as four or eight.

Using six SSCs, for 32 code groups and two possible PSCH time slots, requires 653 real additions and 28 real multiplications at the UE $\mathbf{32_1}$ to identify the code group/PSCH time slot index. For the decision, no additions or multiplications are required. Accordingly, reducing the number of transmitted SSCs in the PSCH time slot reduces the processing at the UE $\mathbf{32_1}$.

Alternately, to reduce the number of SSCs even further quadrature phase shift keying (QPSK) modulation is used. To reduce the SSC number, each SSC signal is sent on either an In-phase (I) or Quadrature (Q) component of the PSCH. One extra

bit of data associated with either using the I or Q carrier is used to distinguish the code group/PSCH time slots. As a result, the number of SSCs, M, required by **Equation 6** is reduced by one.

For instance, to distinguish 32 code groups and two possible PSCH time slots, five SSCs (M = 5) are required. The code groups are divided in half (code groups 1-16 and code groups 17-32). When the SSCs are transmitted on the I carrier, it restricts the code groups to the lower half (code groups 1-16) and when the SSCs are transmitted on the Q carrier, it restricts the code groups to the upper half (code groups 17-32). The five SSCs distinguish between the remaining sixteen possible code groups and two possible PSCH time slots.

A simplified base station $\mathbf{30_1}$ and UE $\mathbf{32_1}$ using QPSK modulation are shown in **Figure 7**. The base station $\mathbf{30_1}$ generates the appropriate SSC signals for its code group and PSCH time slot using the SSC spread spectrum signal generators $\mathbf{68_1}$ to $\mathbf{68_M}$. Also based on the base station's code group/PSCH time slot index, switches $\mathbf{90_1}$ to $\mathbf{90_M}$ either switch the outputs of the generators $\mathbf{68_1}$ to $\mathbf{68_M}$ to an I combiner **86** or a Q combiner **88**. The combined I signal which includes the PSC signal is modulated by an I modulator **82** prior to transmission. The combined Q signal is modulated by a Q modulator **84** prior to transmission. One approach to produce the Q carrier for modulating the signal is to delay the I carrier by ninety degrees by a delay device **98**. The UE $\mathbf{32_1}$ demodulates the received signals with both an I demodulator **92** and a Q demodulator **94**. Similar to the base station $\mathbf{30_1}$, the UE $\mathbf{32_1}$ may produce a Q carrier for demodulation using a delay device **96**. Obtaining binary

data representing the lower or higher half of the 16 code groups and PSCH time slot index is the same as applying BPSK demodulation on the I and Q components of the received signal respectively. The I matched filters $\mathbf{100_1}$ to $\mathbf{100_M}$ are used by the processor **80** to determine whether any SSC signals were sent on the I component of the PSCH. A decision variable, I_{dvar}, is obtained such as by using **Equation 11**.

$$I_{dvar} = |rx_1| + |rx_2| + ... + |rx_m| \qquad \textbf{Equation 11}$$

$|rx_i|$ is the magnitude of the real component (I component) of the i^{th} SSC matched filter output. Likewise, the Q matched filters $\mathbf{102_1}$ to $\mathbf{102_M}$ are used by the processor **80** to determine whether any SSC signals were sent on the Q component of the PSCH. A decision variable, Q_{dvar}, is obtained such as by using **Equation 12**.

$$Q_{dvar} = |ix_1| + |ix_2| + ... + |ix_M| \qquad \textbf{Equation 12}$$

$|ix_i|$ is the magnitude of the imaginary (Q component) of the i^{th} SSC matched filter outputs.

If I_{dvar} is greater than Q_{dvar}, the SSC signals were transmitted on the I component. Otherwise, the SSC signals were transmitted on the Q component.

Another approach using QPSK modulation to reduce the number of SSC signals transmitted is depicted in **Figure 8**. Instead of transmitting the number of SSCs of **Figure 7**, the number of SSCs, M, representing the code group number and

PSCH time slot index is reduced by one. To regain the one lost bit of information by reducing the SSCs, two sets of M SSCs are used. For instance using 32 code groups and two possible PSCH time slots, one set, SSC_{11} to SSC_{14}, is assigned to the lower code groups, such as code groups 1 to 16, and the second set, SSC_{21} to SSC_{24}, is assigned to the upper code groups, such as code groups 17 to 32. For the lower code group, sending SSC_{11} to SSC_{14} on the I carrier restricts the code groups to 1 to 8. The Q carrier restricts the code groups to 9 to 16. Likewise, for the upper code group, in phase SSC_{21} to SSC_{24} restricts the code groups to 17 to 24 and Q SSC_{21} to SSC_{24} restricts the code groups to 25 to 32. As a result, the maximum number of SSCs transmitted at one time is reduced by one. By reducing the number of SSCs, the interference between SSC signals is reduced. Reduced interference between SSCs allows higher transmission power levels for each SSC signal easing detection at the UE $\mathbf{32_1}$.

A simplified base station $\mathbf{30_1}$ and UE $\mathbf{32_1}$ implementing the reduced SSC approach is shown in **Figure 8**. At the base station $\mathbf{30_1}$, two sets of M SSC spread spectrum signal generators $\mathbf{104_{11}}$ to $\mathbf{104_{2M}}$ generate the SSC signals corresponding to the base station's code group and PSC time slot. The corresponding SSC signals are switched using switches $\mathbf{106_{11}}$ to $\mathbf{106_{2M}}$ to either an I **82** or Q modulator **84** as appropriate for that base station's code group and PSCH time slot. At the UE $\mathbf{32_1}$, an I set of matched filters $\mathbf{108_{11}}$ to $\mathbf{108_{2Q}}$ is used to determine if any of the SSCs were sent on the I carrier. A Q set of matched filters $\mathbf{110_{11}}$ to $\mathbf{110_{2M}}$ is used to determine

if any of the SSCs were sent on the Q carrier. By detecting the transmitted I and Q SSCs, the processor **80** determines the base station's code group and PSCH time slot.

One approach to determining which of 32 code groups and two possible PSCH time slots is used by the base station $\mathbf{32_1}$ follows. After the processor **80** accumulates data from matched filters $\mathbf{110_{11}}$ to $\mathbf{110_{24}}$, the code group set, either SSC_{11} to SSC_{14} or SSC_{21} to SSC_{24}, is determined using **Equations 13** and **14**.

$$var_set\ 1 = |r\ x_{11}| + |i\ x_{12}| + \ldots + |r\ x_{14}| + |i\ x_{14}| \qquad \textbf{Equation 13}$$

$$var_set\ 2 = |r\ x_{21}| + |i\ x_{22}| + \ldots + |r\ x_{24}| + |i\ x_{24}| \qquad \textbf{Equation 14}$$

The values, rx_{11} to rx_{24}, are the number of accumulated matches for a respective SSC, SSC_{11} to SSC_{24}, received in the I channel. Similarly, ix_{11} to ix_{24} are the number of accumulated matches for the Q channel for SSC_{11} to SSC_{24}. **Equations 13** and **14** require a total of 16 real additions. var_set 1 represents the total accumulations of the first SSC set, SSC_{11} to SSC_{14}. var_set 2 represents the total accumulations of the second SSC set, SSC_{21} to SSC_{24}. The processor **80** compares var_set 1 to var_set 2 and the larger of the two variables is presumed to be the SSC set transmitted by the base station $\mathbf{32_1}$.

To determine whether the SSCs were transmitted on the I or Q channel, **Equations 15** and **16** are used.

$$var_I = |r\ x_{p1}| + \ldots + |r\ x_{p4}| \qquad \textbf{Equation 15}$$

$$var_Q = |i\ x_{p1}| + \ldots + |i\ x_{p4}| \qquad \textbf{Equation 16}$$

If var_set 1 is selected as being larger than var_set 2, the value of p is one. Conversely, if var_set 2 is larger, the value of p is two. var_I is the accumulated values for the selected set on the I carrier and var_Q is the accumulated values on the Q carrier. The larger of the two variables, var_I and var_Q, is presumed to be the channel that the selected set was transmitted over. By ordering the additions in **Equations 13** and **14**, the values of var_I and var_Q can be determined simultaneously with var_set 1 and var_set 2. Accordingly, determining whether the I or Q carrier was used requires no additional additions. As a result, using QPSK modulation and two SSC sets requires 803 real additions and 36 real multiplications in each time slot and 16 real additions for the decision.

Figures 9 to **15** are graphs illustrating the performance for distinguishing 32 code groups/two PSCH time slots of systems using 32 SSCs **128**, 17 SSCs **124** and 6 SSCs **126**. The graphs show the performance for various simulated channel conditions. The simulations accumulated the SSC matches at the UE $\mathbf{32_1}$ over four or eight PSCH time slots and compared the probability of an incorrect synchronization to the channel's signal to noise ratio (SNR) in decibels.

The **Figure 9** simulation uses an additive white gaussian noise (AWGN) channel and accumulation over eight PSCH time slots. The **Figure 10** simulation

uses a single path Rayleigh fading channel with a six kilohertz (kHz) frequency offset and accumulation over four PSCH time slots. The **Figure 11** simulation is the same as the **Figure 10** simulation except the accumulation was over eight PSCH time slots. The **Figure 12** simulation uses an ITU channel with three multipaths with a UE 32_1 moving at 100 kilometers per hour (km/h) and accumulation over eight PSCH time slots. The **Figure 13** simulation uses an ITU channel with three multipaths having six kilohertz (kHz) frequency offset and a UE 32_1 moving at 500 km/h with accumulation over eight PSCH time slots. The **Figure 14** simulation uses a single path Rayleigh channel having 10 kHz frequency offset with accumulation over eight PSCH time slots. The **Figure 15** simulation uses an ITU channel with three multipaths having 10 kHz frequency offset and the UE 32_1 moving at 500 km/h with accumulation over eight PSCH time slots.

Under the simulated conditions of **Figures 14** and **15**, 6 SSCs **128** outperforms the other techniques **124, 126**. As shown in **Figures 9** to **13**, 6 SSCs **128** performs favorably in comparison to the other techniques **124, 126**.

Figure 16 is a graph of the simulated performance of 6 SSCs **114** using BPSK and the two sets of 4 SSCs **112** using QPSK modulation. The simulation used an eight PSCH time slot accumulation of the matches for each SSC and transmission over an AWGN channel. As shown, two set QPSK modulation **112** outperformed 6 SSC BPSK modulation **114**.

Figure 17 illustrates the performance of BPSK and two set QPSK modulation accumulating matches over four and eight PSCH time slots. The SSCs were

simulated as being transmitted over a single path Rayleigh channel. Performance for both modulation schemes improves with additional time slot correlations. Two set QPSK modulation for four PSCH time slots **116** and eight PSCH time slots **120** outperforms BPSK modulation for four PSCH time slots **118** and eight PSCH time slots **122**, respectively.

* * *

CLAIMS

What is claimed is:

1. A method for a user equipment to synchronize both timing and a code group assigned to a base station in a time division duplex code division multiple access communication system, the system communicating using time slots in repeating frames, the assigned code group being one out of a predetermined number N of possible code groups, the method comprising:

transmitting from the base station a primary code synchronization signal in a selected time slot in a primary code synchronization channel, the primary code synchronization channel using at least one of the frame time slots for communication;

receiving at the user equipment the primary code synchronization signal;

time synchronizing the user equipment with a received timing of the primary code synchronization signal;

associating each of said N code groups with a unique combination of secondary signals from a set of secondary signals which does not exceed $(\log_2 N) + 1$ in number;

transmitting from the base station selected secondary synchronization signals out of said set of secondary synchronization signals; corresponding to the unique combination of secondary signals associated with the assigned code group;

receiving and identifying at the user equipment the transmitted selected secondary synchronization signals; and

based on in part the identified selected secondary synchronization signals, determining the base station's assigned code group.

2. The method of claim 1 wherein the associating associates a selected time slot in the frames with the unique combination of secondary signals.

3. The method of claim 1 wherein each of a plurality of base stations transmit a primary code synchronization signal and the user equipment accumulates chip matches over a set number of frames to determining which of the plurality of base station to communicate.

4. The method of claim 3 wherein the set number of frames is forty.

5. The method of claim 1 wherein the transmitted secondary signals are modulated with binary data.

6. The method of claim 5 wherein the modulated binary data identifies the base station's code group.

7. The method of claim 1 wherein the transmitted secondary signals are selectively transmitted using an in-phase or quadrature phase carrier.

8. The method of claim 1 further comprising correlating the primary code synchronization signal with the transmitted secondary signals to obtain phrase reference.

9. The method of claim 8 wherein the primary code synchronization signal is not modulated with data.

10. The method of claim 8 further comprising derotating the received secondary signals based on in part the primary code synchronization signal phase reference.

11. The method of claim 10 further comprising match filtering the received secondary signals and accumulating results of the match filtering over a set number of frames.

12. A wireless time division duplex code division multiple access communication system using time slots in repeating frames, a base station having an assigned code group out of a predetermined number N of possible code groups, the system comprising:

the base station comprising:

means for transmitting a primary code synchronization signal in a selected time slot in a primary code synchronization channel, the primary code

synchronization channel using at least one of the frame time slots for communication;

means for associating each of said N code groups with a unique combination of secondary signals from a set of secondary signals which does not exceed $(\log_2 N) + 1$ in number; and

a user equipment comprising:

means for receiving the primary code synchronization signal;

means for time synchronization with a received timing of the primary code synchronization signal;

means for receiving and identifying the transmitted selected secondary synchronization signals; and

means for determining the base station's assigned code group, based on in part the identified selected secondary synchronization signals.

13. The system of claim 12 wherein the receiving and identifying means comprises a plurality of matched filters, at least one matched filter is matched to each secondary signal out of the set of secondary signals.

14. The system of claim 13 wherein the secondary signals are transmitted either on an in-phase or quadrature phase carrier and the plurality of matched filters having an in-phase and a quadrature phase matched filter for each secondary signal out of the set of secondary signals.

15. The system of claim 12 wherein the associating means associates a selected time slot in the frames with the unique combination of secondary signals.

16. The system of claim 12 wherein the base station is one of a plurality of base stations, each base station transmits a primary code synchronization signal and the user equipment further comprising means for accumulating chip matches over a set number of frames to determine which of the plurality of base stations to communicate.

17. The system of claim 16 wherein the set number of frames is forty.

18. The system of claim 12 wherein the transmitted secondary signals are selectively transmitted using an in-phase or quadrature phase carrier.

19. The system of claim 12 wherein the user equipment further comprises means for correlating the primary code synchronization signal with the transmitted secondary signals to obtain phase reference.

20. The system of claim 19 wherein the primary code synchronization signal is not modulated with data.

21. The system of claim 19 wherein the user equipment further comprises means for derotating the received secondary signals based on in part the primary code synchronization signal phase reference.

22. The system of claim 21 wherein the user equipment further comprises means for matched filtering the received secondary signals and means for accumulating results of the match filtering over a set number of frames.

23. A synchronization signal for use in a wireless time division duplex communication system, the time division duplex communication system using time slots in repeating frames for communication, the synchronization signal is transmitted from a base station to identify a code group associated with the base station, the synchronization signal comprising:

a spreading code associated with the base station; and

binary bits modulated by the spreading code using binary phase shift keying.

24. The signal of claim 23 wherein the binary bits are produced by combining a binary code group identifier with a selected row of a Hadamarak matrix.

25. The signal of claim 24 wherein the selected row is from a set of possibly selected rows; the possibly selected rows comprising row 24, 40, 56, 104, 120 and 136.

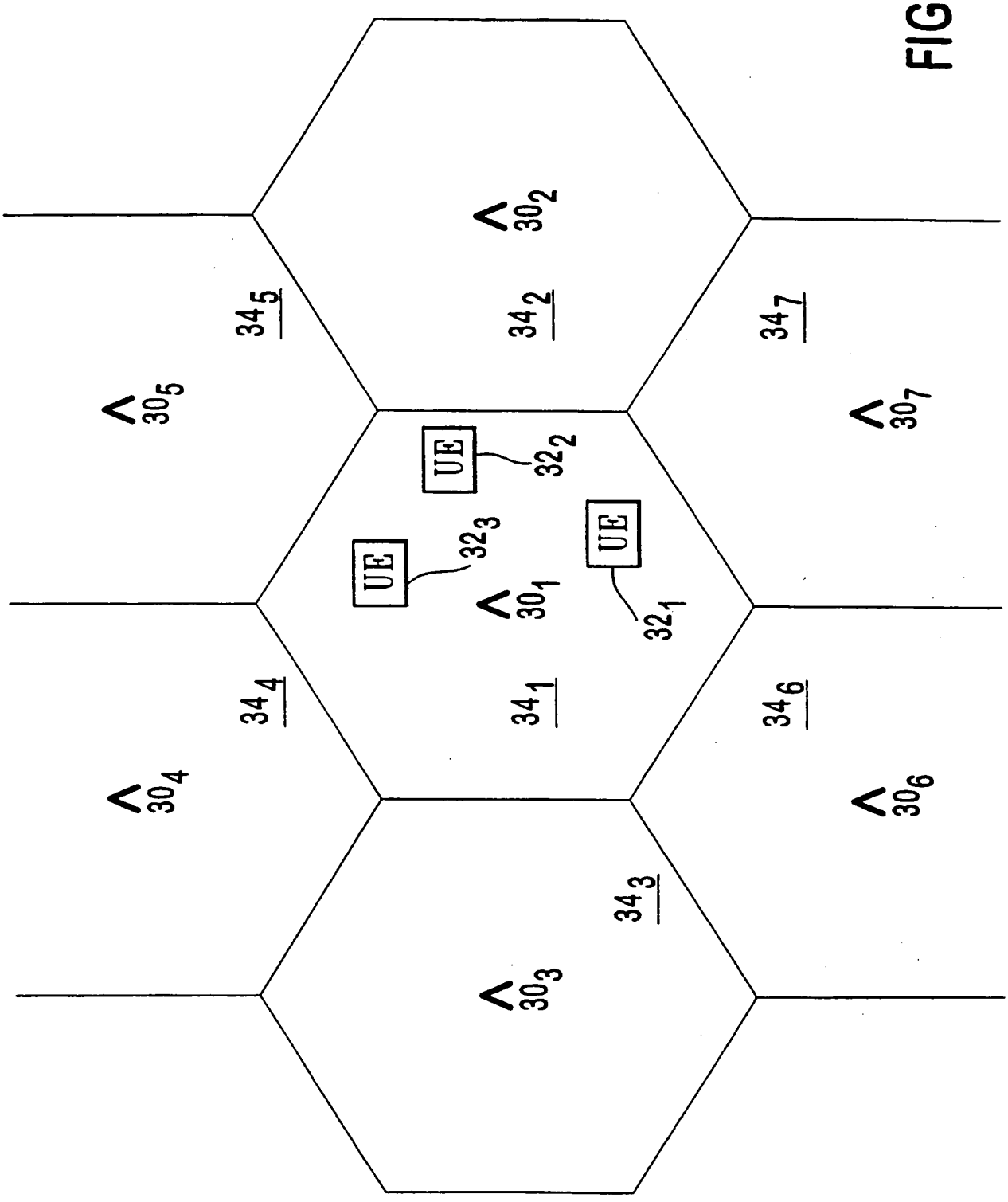
26. The signal of claim 23 wherein the signal is transmitted at a predetermined time offset from a time slots leading boundary.

27. The signal of claim 23 wherein the base station also transmits another signal, both the another signal and the synchronization signal are spread with the spreading code.

28. The signal of claim 27 wherein both the another signal and the synchronization signal are transmitted at a same predetermined time offset from a time slots leading boundary.

29. The signal of claim 23 wherein the synchronization signal is selectively transmitted using an in-phase or quadrature phase carrier.

FIG. 1


30_2
34_5
34_2
34_7
30_5
30_7
UE
32_2
UE
32_3
UE
32_1
30_1
34_4
34_1
34_6
30_4
30_6
34_3
30_3

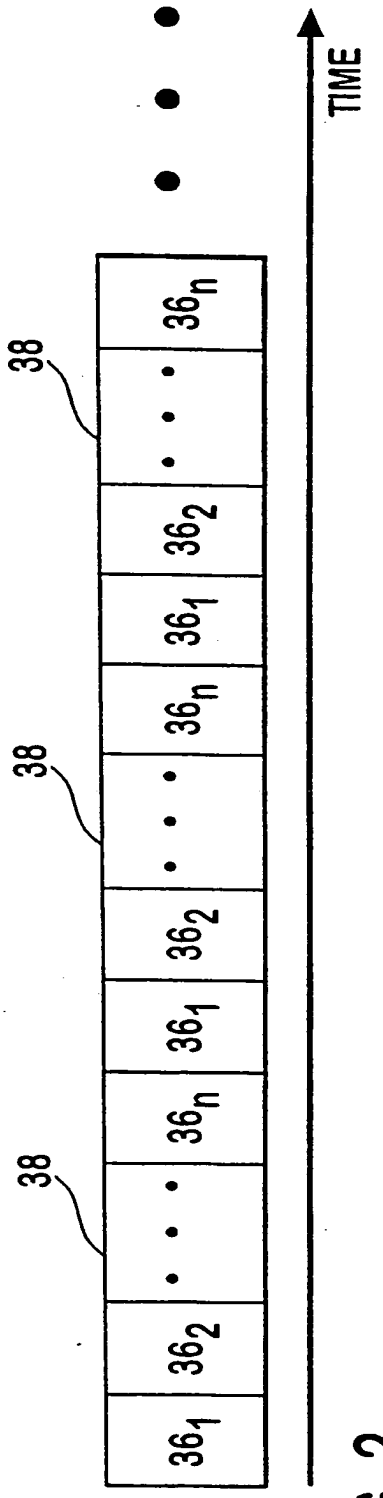

TIME
38
38
38
36_1
36_2
36_n
36_1
36_2
36_n
36_1
36_2
36_n

FIG. 2

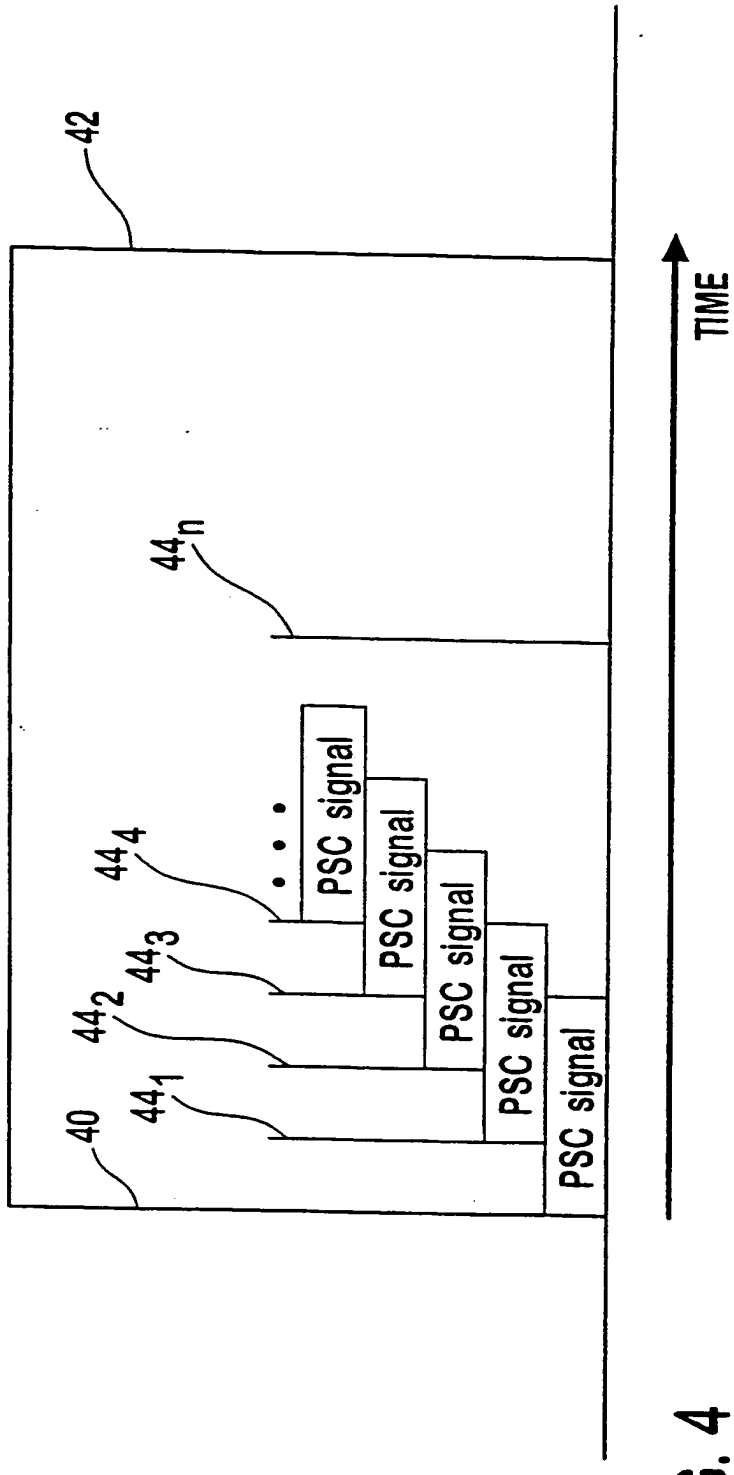

42
40
44_1
44_2
44_3
44_4
44_n
PSC signal
PSC signal
PSC signal
PSC signal
TIME

FIG. 4

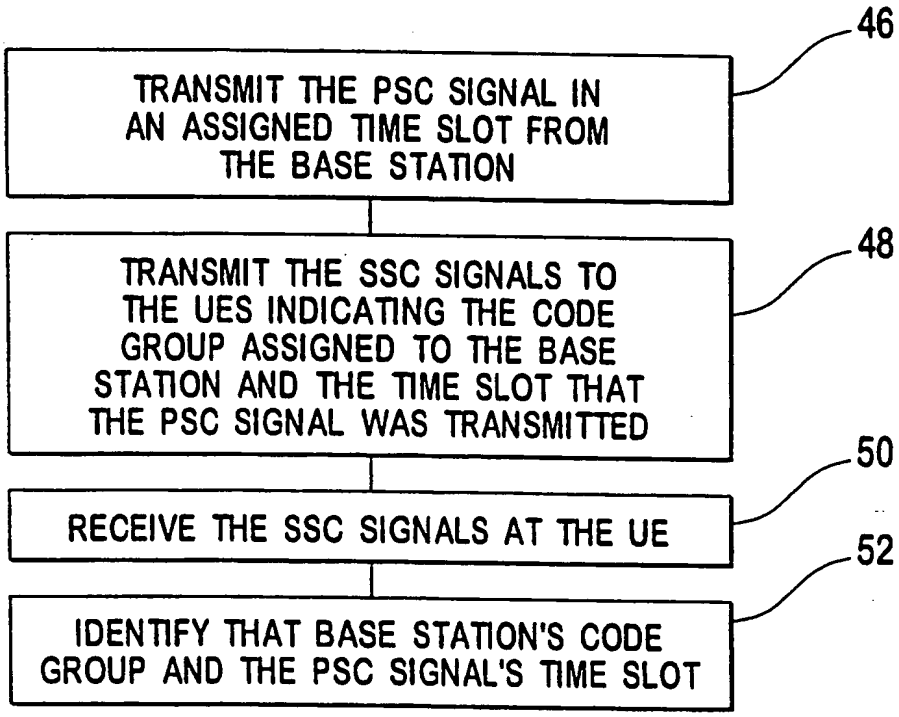

46
TRANSMIT THE PSC SIGNAL IN AN ASSIGNED TIME SLOT FROM THE BASE STATION
48
TRANSMIT THE SSC SIGNALS TO THE UES INDICATING THE CODE GROUP ASSIGNED TO THE BASE STATION AND THE TIME SLOT THAT THE PSC SIGNAL WAS TRANSMITTED
50
RECEIVE THE SSC SIGNALS AT THE UE
52
IDENTIFY THAT BASE STATION'S CODE GROUP AND THE PSC SIGNAL'S TIME SLOT

FIG. 3

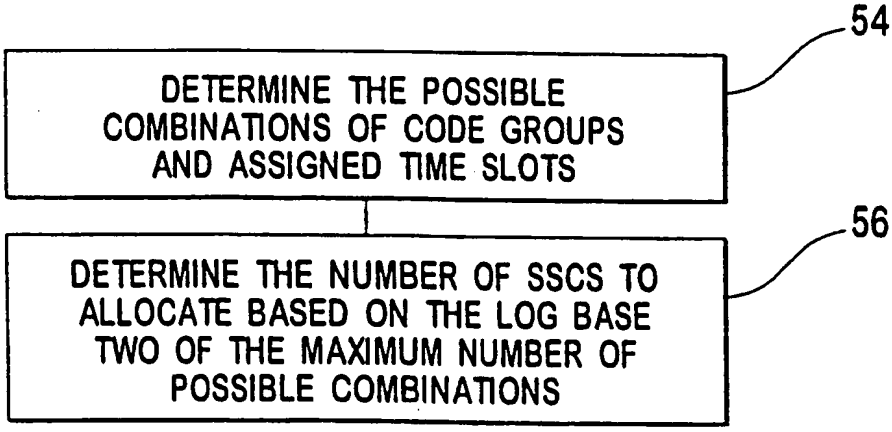

54
DETERMINE THE POSSIBLE COMBINATIONS OF CODE GROUPS AND ASSIGNED TIME SLOTS
56
DETERMINE THE NUMBER OF SSCS TO ALLOCATE BASED ON THE LOG BASE TWO OF THE MAXIMUM NUMBER OF POSSIBLE COMBINATIONS

FIG. 6

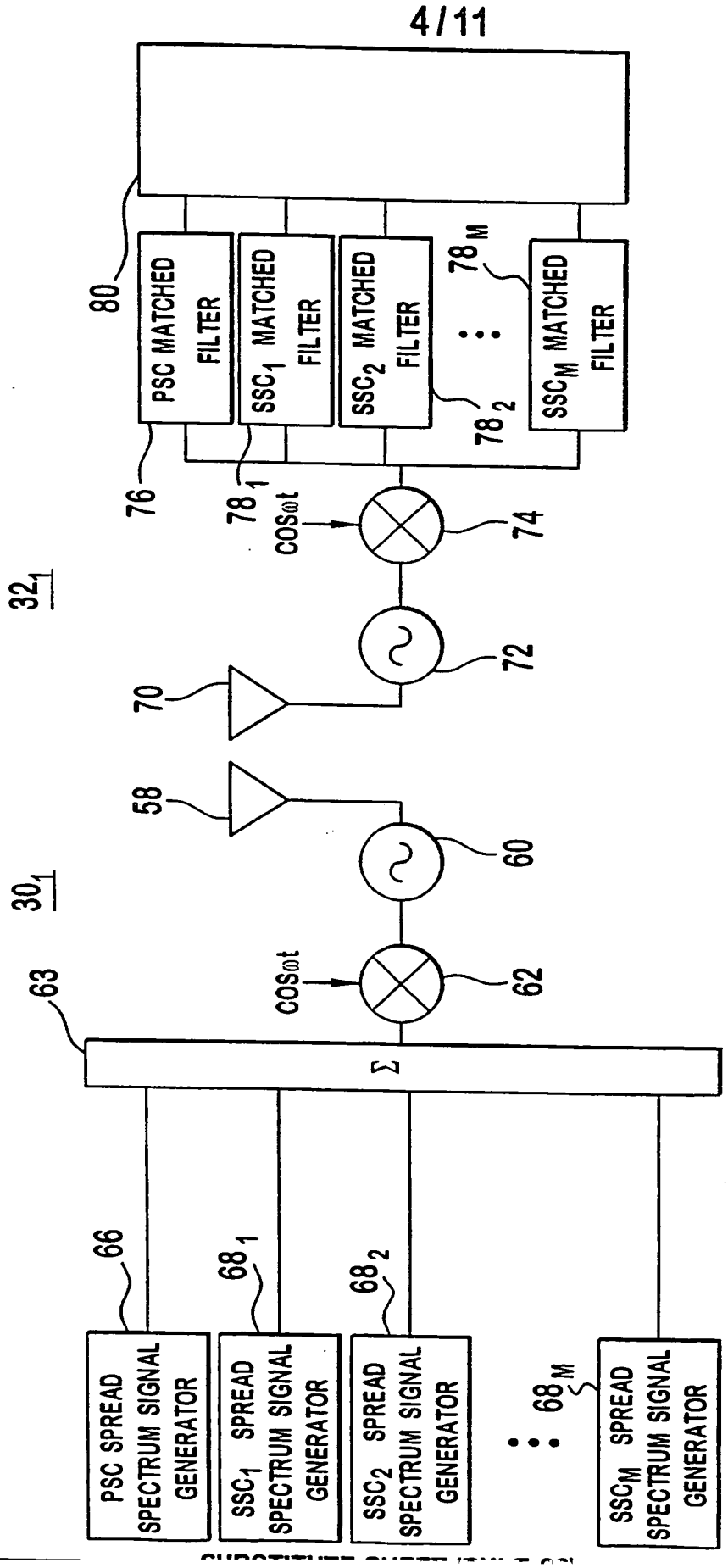

PSC SPREAD SPECTRUM SIGNAL GENERATOR
SSC1 SPREAD SPECTRUM SIGNAL GENERATOR
SSC2 SPREAD SPECTRUM SIGNAL GENERATOR
SSCM SPREAD SPECTRUM SIGNAL GENERATOR
66
68 1
68 2
68 M
63
Σ
30 1
cosωt
62
60
58
32 1
cosωt
74
72
70
76
78 1
78 2
78 M
PSC MATCHED FILTER
SSC1 MATCHED FILTER
SSC2 MATCHED FILTER
SSCM MATCHED FILTER
80

FIG. 5

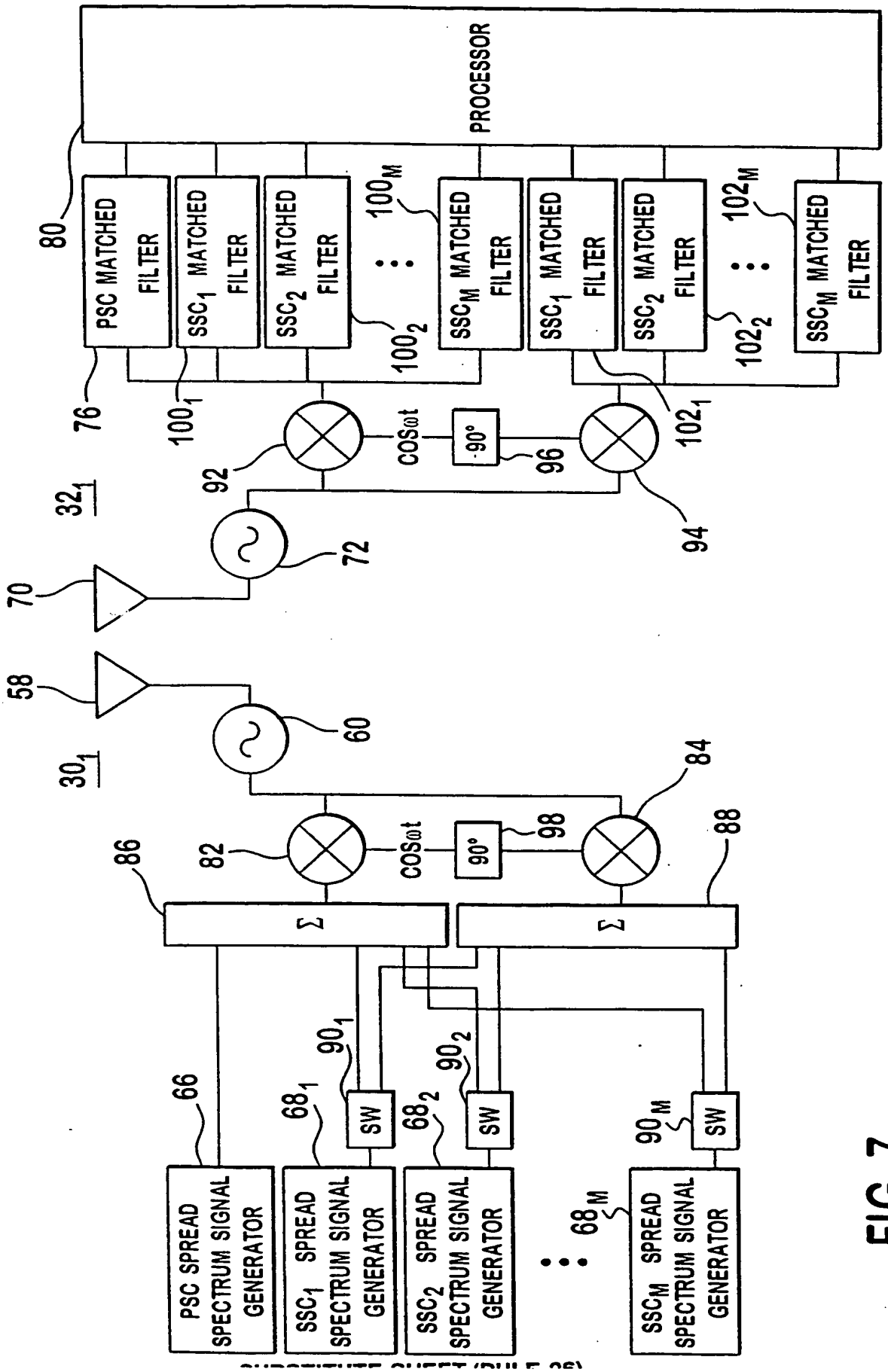
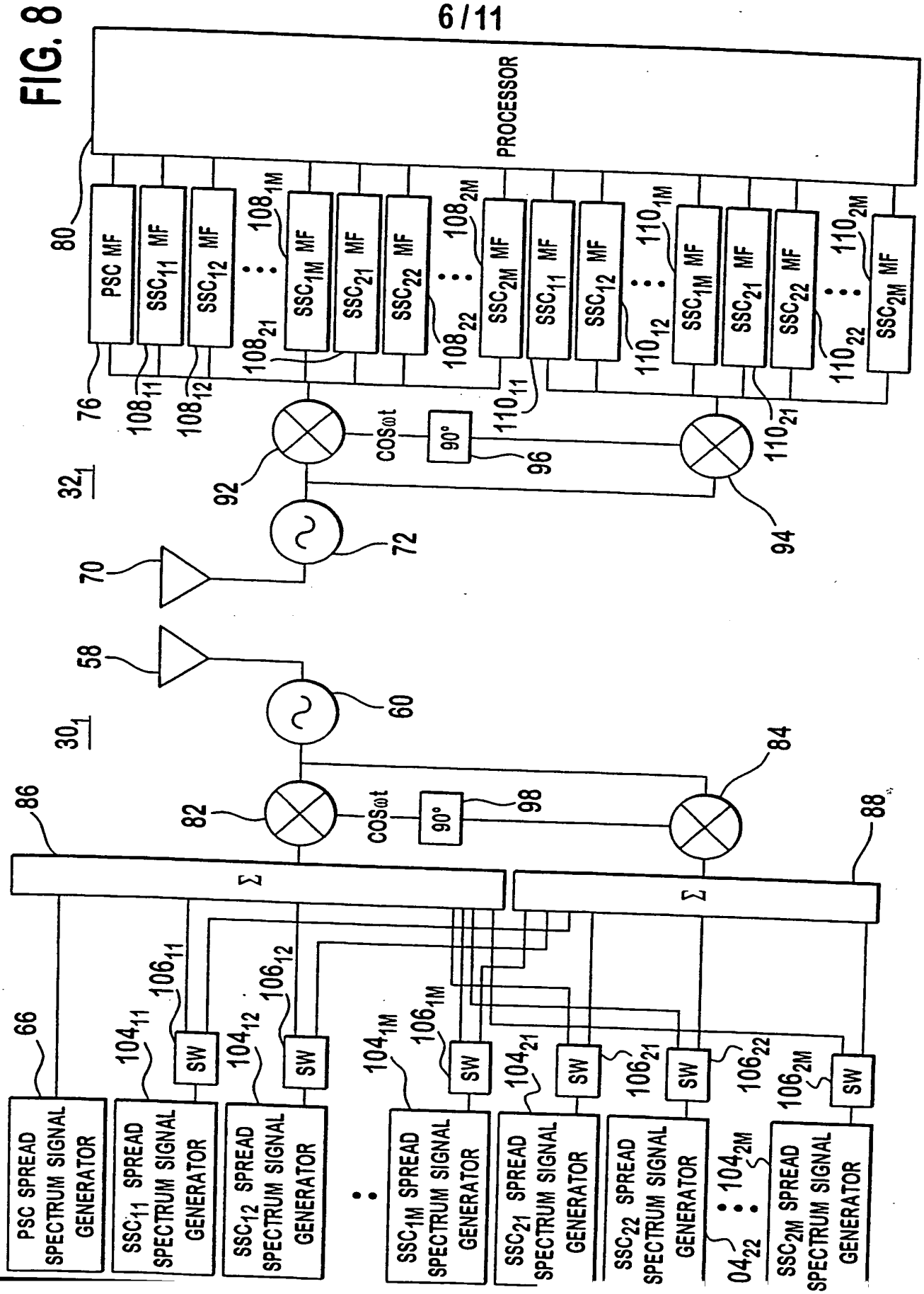

PROCESSOR
80
PSC MATCHED FILTER
SSC1 MATCHED FILTER
SSC2 MATCHED FILTER
SSCM MATCHED FILTER
SSC1 MATCHED FILTER
SSC2 MATCHED FILTER
SSCM MATCHED FILTER
100M
100 2
102M
102 2
76
100 1
102 1
92
cosωt
-90°
96
94
32 1
72
70
58
60
30 1
84
82
cosωt
90°
98
88
86
Σ
Σ
66
68 1
90 1
68 2
90 2
68 M
90M
SW
SW
SW
PSC SPREAD SPECTRUM SIGNAL GENERATOR
SSC1 SPREAD SPECTRUM SIGNAL GENERATOR
SSC2 SPREAD SPECTRUM SIGNAL GENERATOR
SSCM SPREAD SPECTRUM SIGNAL GENERATOR

FIG. 7

FIG. 8


PROCESSOR
80
PSC MF
SSC11 MF
SSC12 MF
SSC1M MF
SSC21 MF
SSC22 MF
SSC2M MF
SSC11 MF
SSC12 MF
SSC1M MF
SSC21 MF
SSC22 MF
SSC2M MF
76
108 11
108 12
108 21
108 22
108 1M
108 2M
110 11
110 12
110 21
110 22
110 1M
110 2M
32 1
92
94
96
cosωt
90°
72
70
58
60
30 1
82
84
98
86
88
Σ
Σ
66
SW
104 11
106 11
104 12
106 12
104 1M
106 1M
104 21
106 21
106 22
106 2M
PSC SPREAD SPECTRUM SIGNAL GENERATOR
SSC11 SPREAD SPECTRUM SIGNAL GENERATOR
SSC12 SPREAD SPECTRUM SIGNAL GENERATOR
SSC1M SPREAD SPECTRUM SIGNAL GENERATOR
SSC21 SPREAD SPECTRUM SIGNAL GENERATOR
SSC22 SPREAD SPECTRUM SIGNAL GENERATOR
SSC2M SPREAD SPECTRUM SIGNAL GENERATOR

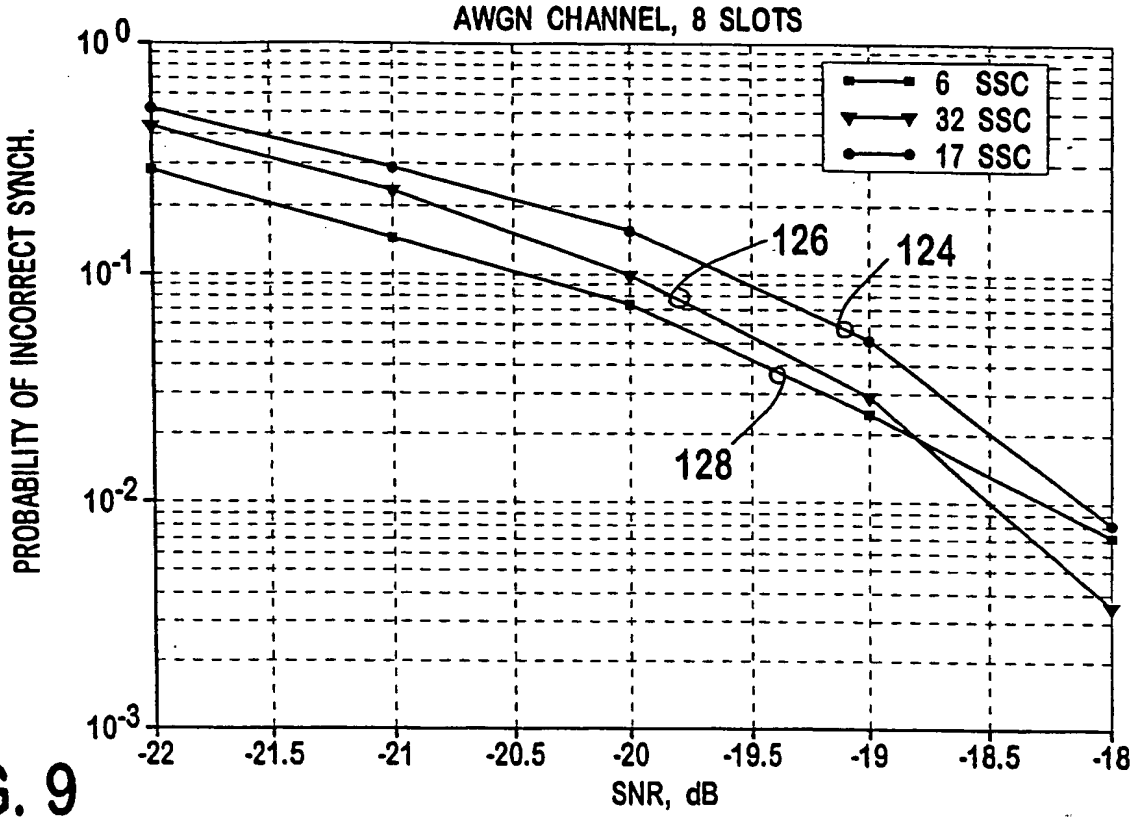

AWGN CHANNEL, 8 SLOTS
PROBABILITY OF INCORRECT SYNCH.
SNR, dB
6 SSC
32 SSC
17 SSC
126
124
128
10^0
10^{-1}
10^{-2}
10^{-3}
-22
-21.5
-21
-20.5
-20
-19.5
-19
-18.5
-18

FIG. 9

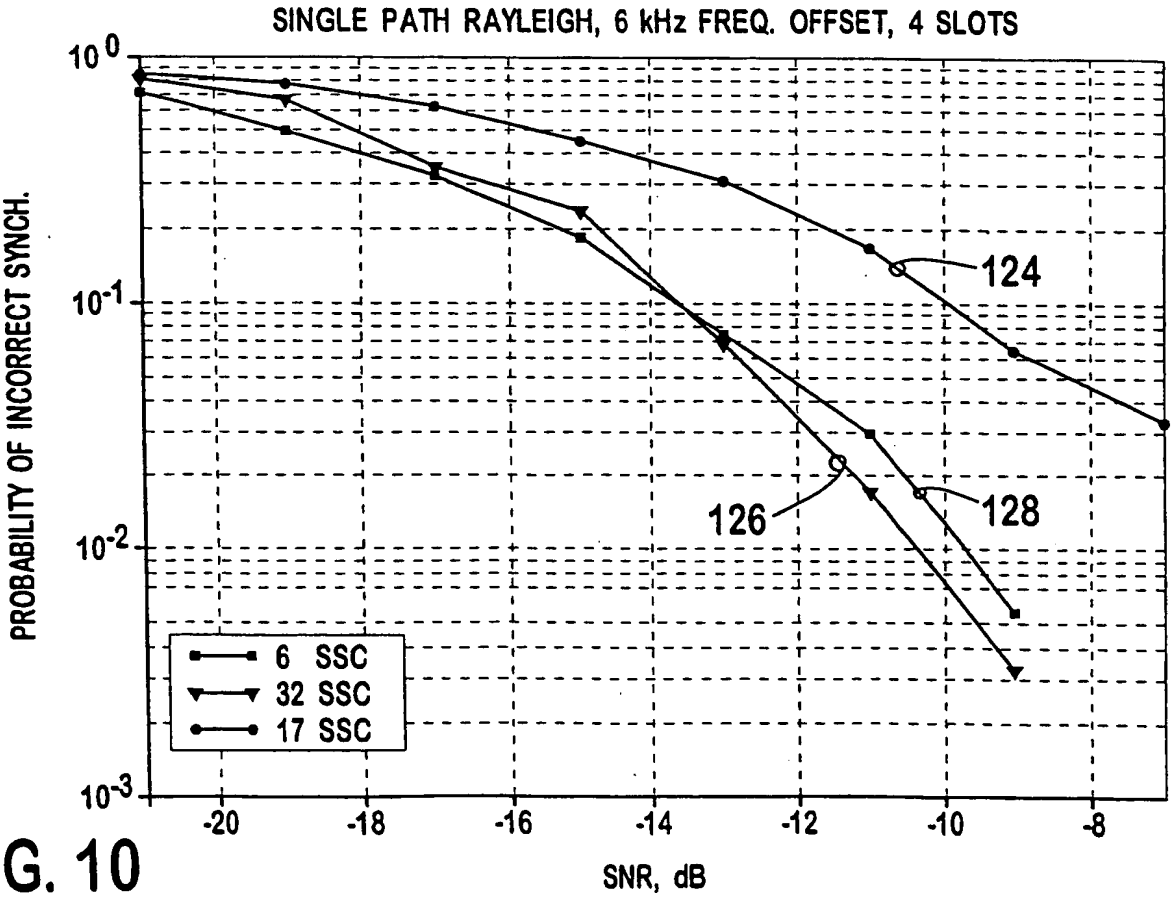

SINGLE PATH RAYLEIGH, 6 kHz FREQ. OFFSET, 4 SLOTS
PROBABILITY OF INCORRECT SYNCH.
SNR, dB
6 SSC
32 SSC
17 SSC
124
126
128
10^0
10^{-1}
10^{-2}
10^{-3}
-20
-18
-16
-14
-12
-10
-8

FIG. 10

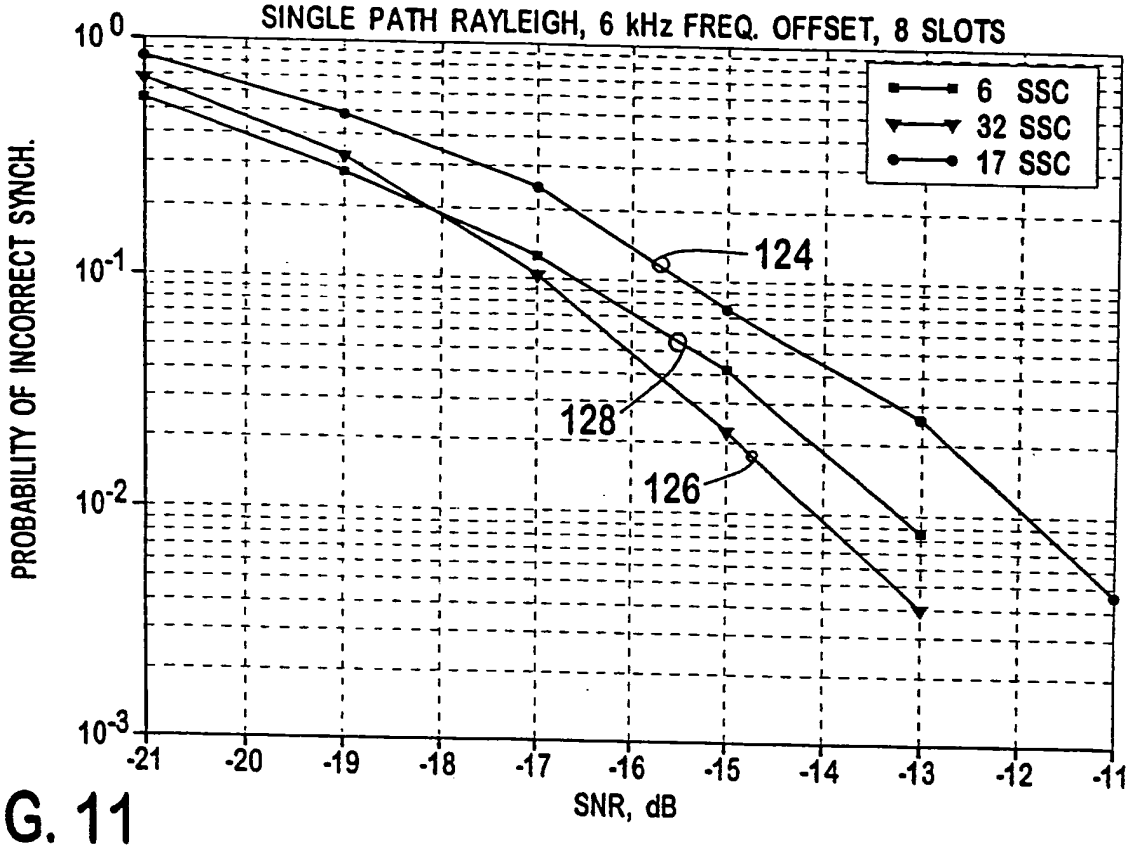

SINGLE PATH RAYLEIGH, 6 kHz FREQ. OFFSET, 8 SLOTS
PROBABILITY OF INCORRECT SYNCH.
SNR, dB
6 SSC
32 SSC
17 SSC
124
128
126
10^0
10^-1
10^-2
10^-3
-21
-20
-19
-18
-17
-16
-15
-14
-13
-12
-11

FIG. 11

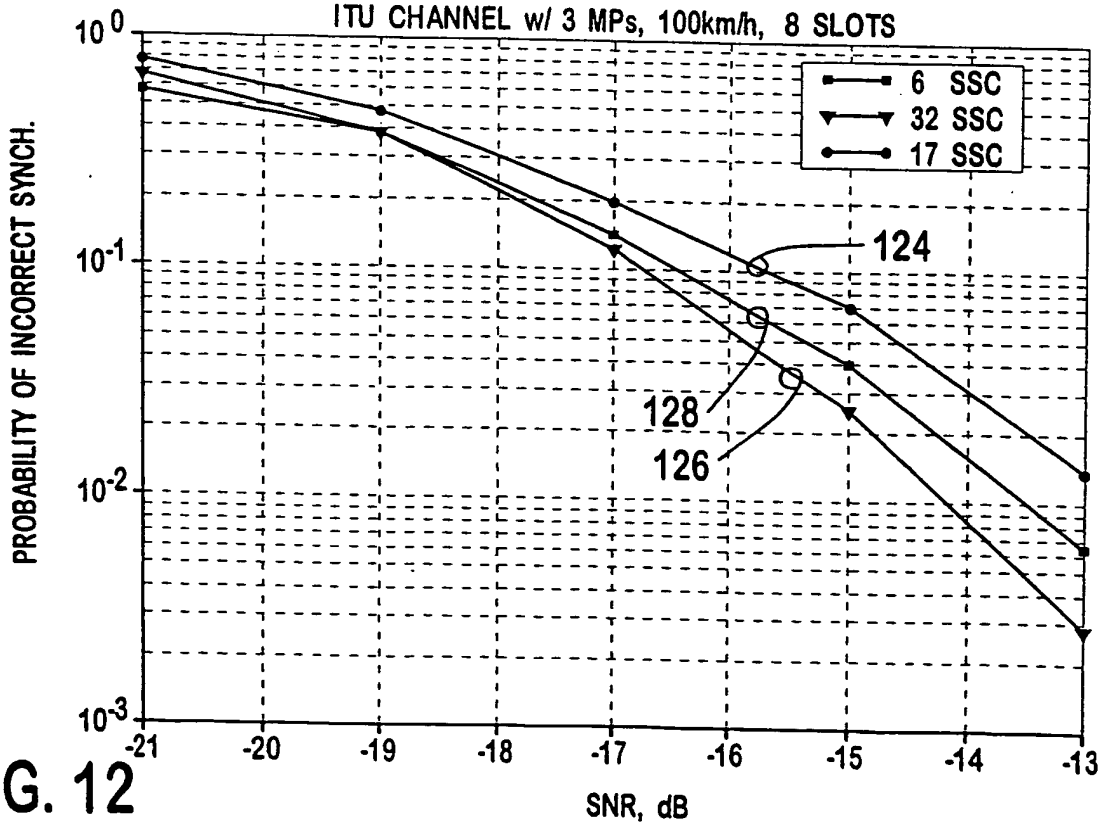

ITU CHANNEL w/ 3 MPs, 100km/h, 8 SLOTS
PROBABILITY OF INCORRECT SYNCH.
SNR, dB
6 SSC
32 SSC
17 SSC
124
128
126
10^0
10^-1
10^-2
10^-3
-21
-20
-19
-18
-17
-16
-15
-14
-13

FIG. 12

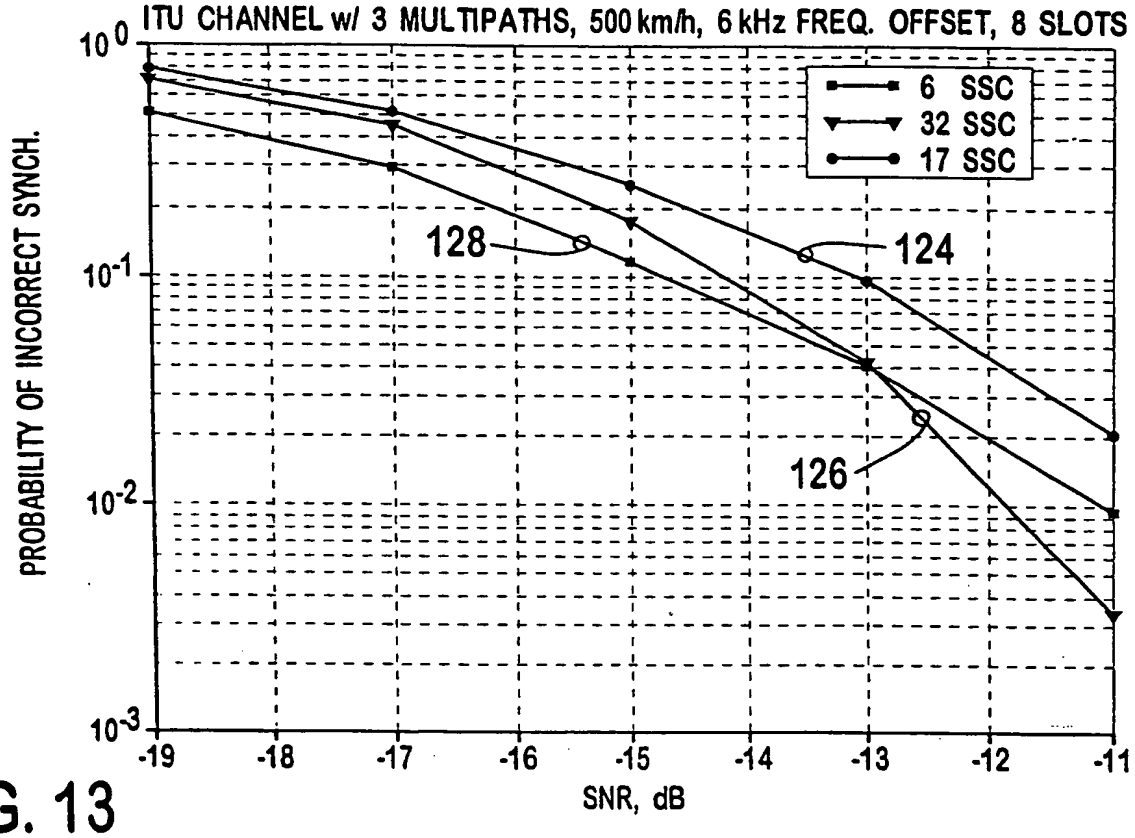

ITU CHANNEL w/ 3 MULTIPATHS, 500 km/h, 6 kHz FREQ. OFFSET, 8 SLOTS
PROBABILITY OF INCORRECT SYNCH.
SNR, dB
6 SSC
32 SSC
17 SSC
128
124
126
10^0
10^{-1}
10^{-2}
10^{-3}
-19
-18
-17
-16
-15
-14
-13
-12
-11

FIG. 13

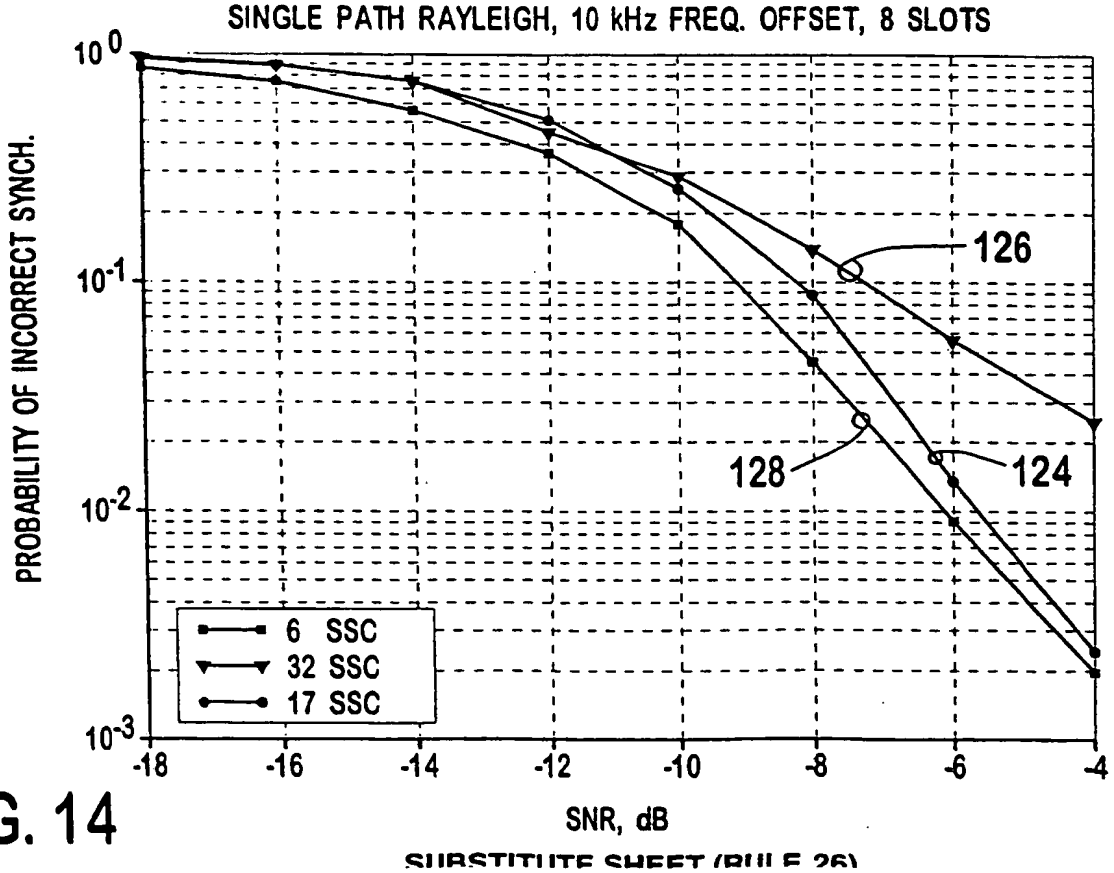

SINGLE PATH RAYLEIGH, 10 kHz FREQ. OFFSET, 8 SLOTS
PROBABILITY OF INCORRECT SYNCH.
SNR, dB
6 SSC
32 SSC
17 SSC
126
128
124
10^0
10^{-1}
10^{-2}
10^{-3}
-18
-16
-14
-12
-10
-8
-6
-4

FIG. 14

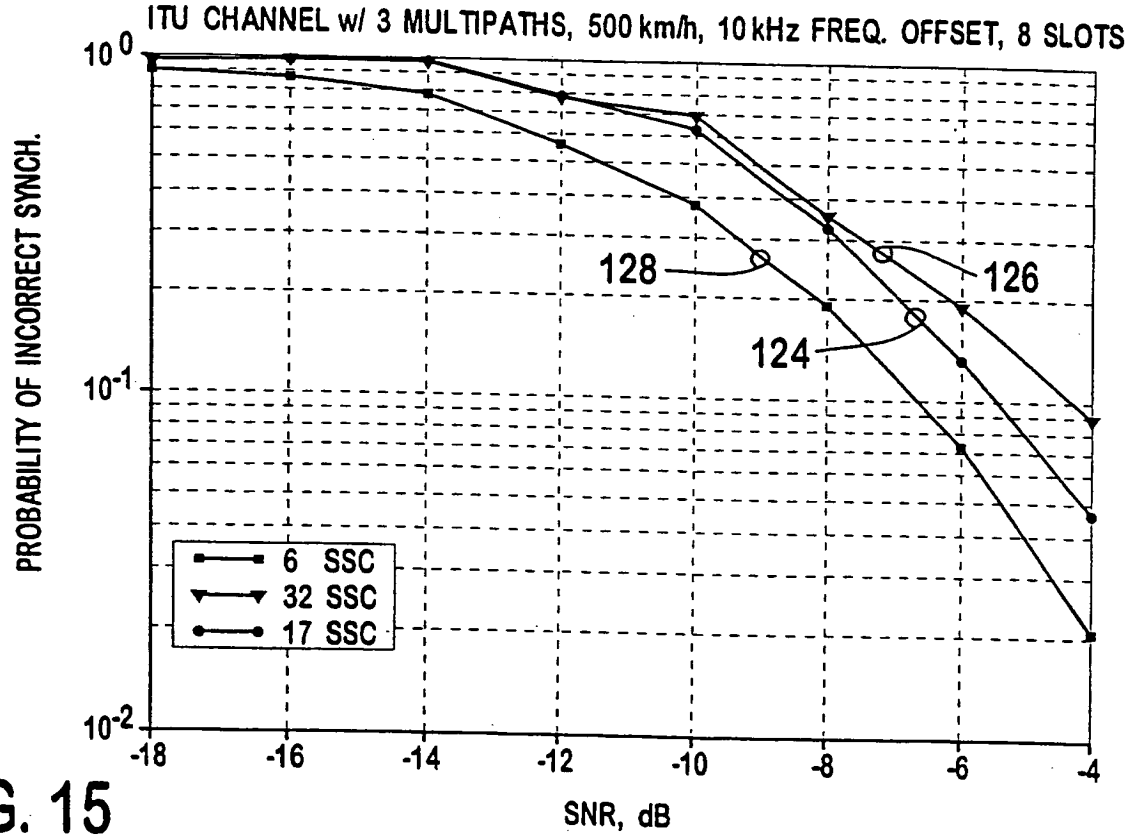

ITU CHANNEL w/ 3 MULTIPATHS, 500 km/h, 10 kHz FREQ. OFFSET, 8 SLOTS
PROBABILITY OF INCORRECT SYNCH.
10^0
10^{-1}
10^{-2}
-18
-16
-14
-12
-10
-8
-6
-4
SNR, dB
6 SSC
32 SSC
17 SSC
128
126
124

FIG. 15

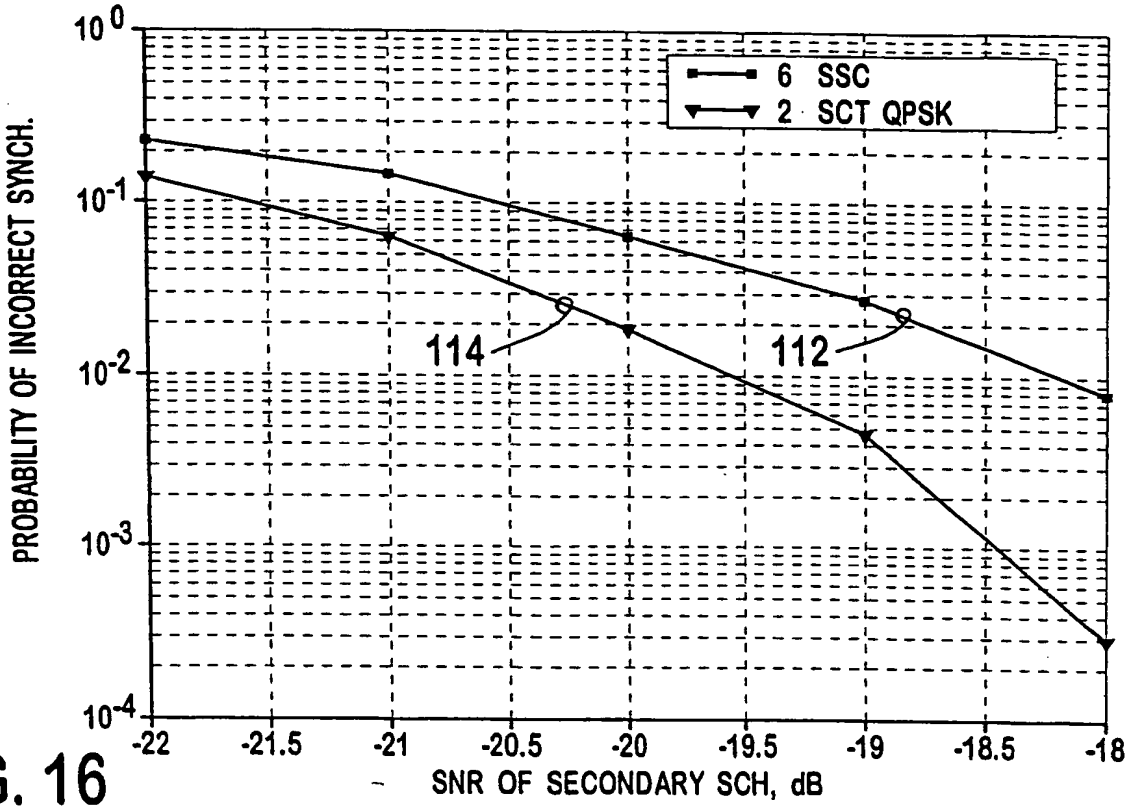

6 SSC
2 SCT QPSK
114
112
PROBABILITY OF INCORRECT SYNCH.
SNR OF SECONDARY SCH, dB

FIG. 16

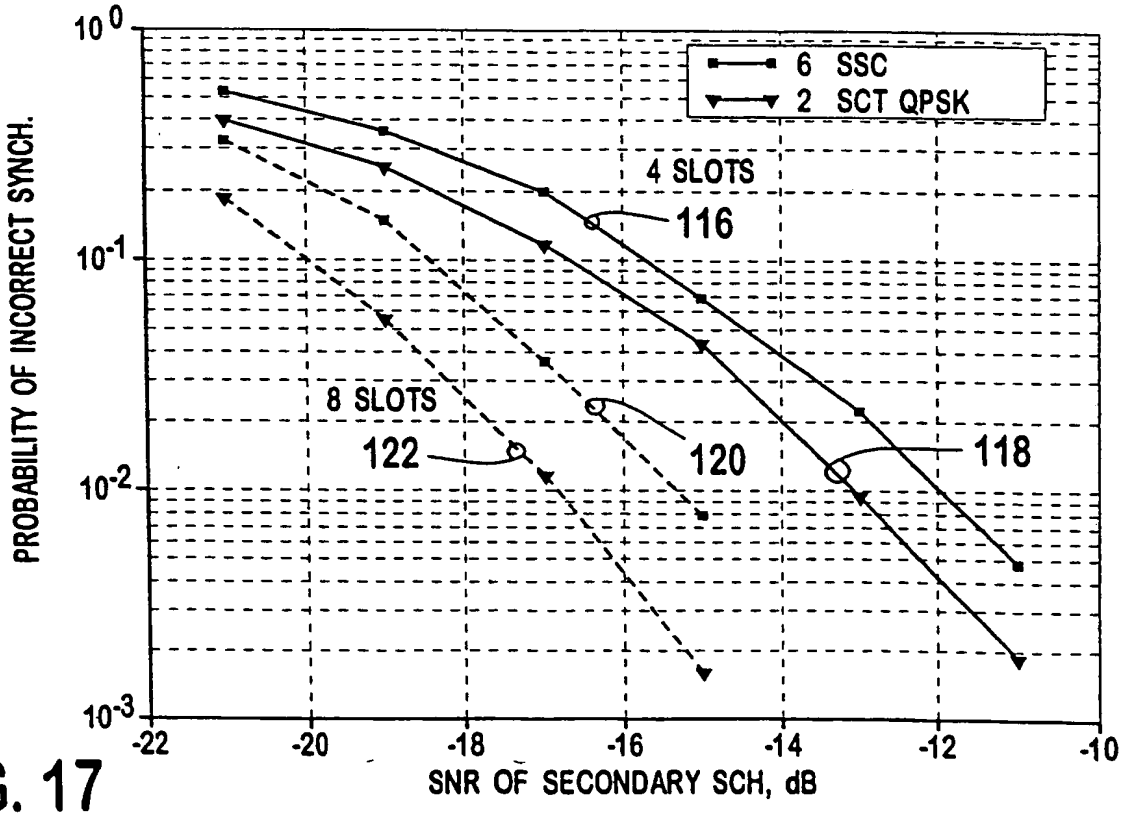

6 SSC
2 SCT QPSK
4 SLOTS
116
8 SLOTS
122
120
118
PROBABILITY OF INCORRECT SYNCH.
SNR OF SECONDARY SCH, dB

FIG. 17

INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/US 00/14339

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 12273 A (ERICSSON TELEFON AB L M) 11 March 1999 (1999-03-11) page 1, line 6 - line 11 page 3, line 9 -page 7, line 20 page 8, line 15 -page 12, line 16	23,26-29
A	---	1-22
X	EUROPEAN TELECOMMUNICATIONS STANDARD INSTITUTE (ETSI): "Universal Mobile Telcommunications System (UMTS);UMTS Terrestrial Radio Access (UTRA); Concept evaluation (UMTS 30.06 version 3.0.0)" TR 101146 V3.0.0, December 1997 (1997-12), XP002131073 the whole document	23,26-29
A	---	1-22
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 August 2000	06/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Larcinese, A

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INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/US 00/14339

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	HIGUCHI K ET AL: "FAST CELL SEARCH ALGORITHM IN DS-CDMA MOBILE RADIO USING LONG SPREADING CODES" IEEE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 47, 4 May 1997 (1997-05-04), pages 1430-1434, XP000738598 ISBN: 0-7803-3660-7 page 1430, left-hand column, line 1 -page 1431, right-hand column, line 20 figure 3; table 1	23,26-29
A	-----	1-22

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intl Jonal Application No
PCT/US 00/14339

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9912273 A	11-03-1999	US 5930366 A	27-07-1999
		AU 8896498 A	22-03-1999
		EP 1010256 A	21-06-2000
		ZA 9807254 A	15-02-1999